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MICROBIAL FUEL CELL FOR ELECTRICITY PRODUCTION

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ABSTRACT

In this research paper I have tried to build the microbial fuel cell using the kitchen waste water like the rice washed water and other household waste as the biomass using the E.coli and C.sporengenes species and tried to measure their potential to produce the electricity.

I also have compared the results of the potential of both the species in production of electric current using different biomass for various incubation time periods. Initially the species were inoculated in their growth media for 24hours to grow at sufficient quantity.

Later on I built the MFC using 2 PAC bottles using the agar-salt bridge. Then I inoculated the species with different biomass separately in separate MFC set up. Further I allowed the species to respire anaerobically and completed the circuit with external connections.

I also connected a multimeter and thus after the incubation the bacterias fed on the biomass and converted the organic matter to electricity which was measured and tabulated graphically. Thus the bacterial potential of electricity production was made practical and their properties were explored.

KEYWORDS: Microbial Fuel Cell, Electricity Production, E.coli and C.sporengenes

Abbreviations

Acetyl Co A- acetyl co enzyme

ADP- adenosine diphosphate

ATP- Adenosine tri phosphate

C- carbon

COD - Chemical oxygen demand

C.sporogenes- *clostridium sporogenes*

Cm- centimeters

E coli- *Escherichia coli*

FADH- Flavin adenosine dinucleotide (reduced form)

Fe-EDTA – Iron ethylene diamine tetra acetic acid

FMN- flavn mono nucleotide

HNQ- hydroxyl naphthoquinone

LAF-laminar air flow

L- litre

mA - milli ampere

MFC – microbial fuel cell

mg/ltr – milligrams per liter

ML-MFC- membraneless microbial fuel cell

mV – milli volts

N-normality

NA – nutrient agar

NB – nutrient broth

NaCl- sodium chloride

NADH- Nicotinamide adenine dinucleotide (reduced form)

OCP- open circuit potential

Ox – oxidizing chemical

PEM- proton exchange membrane

ppm – parts per million

PVC- poly vinyl chloride

Red- reducing chemical

SEM- scanning electron microscopy

TCA- tricarboxylic acid

INTRODUCTION

It has been known for decades that bacteria could produce and generate electricity [1]. But only in the past few years this capability has become more than a laboratory novelty. The MFC is a new form of renewable energy technology that can generate electricity from waste. The reasons for this include latest discoveries, advancement in the field of fuel cell technology and also the need for the development of the renewable forms of the energy for the societal need.

A microbial fuel cell (MFC) or biological fuel cell is a bio-electrochemical system that drives a current by using bacteria and mimicking bacterial interactions found in nature.

Microbial fuel cells produce electricity from organic matters. Using the microbial fuel cells, conversion of the energy to hydrogen is 8 times as high as compared to conventional hydrogen production technologies using conventional fuel cell technology[3].

In MFC, bacteria are separated from cathode so that the respiration is hindered in order to make the bacteria transfer the electrons to the acceptors as a sole mode of respiration thus in MFC the electricity is produced by the decomposition of the organic or biomass by the process of catabolisation.

A typical MFC contains anode and cathode compartments. In the anode, biomass is oxidized by microbes and protons and electrons are liberated. Electrons are transferred to cathode through an external electric circuit. The protons are transferred to cathode through a separator. Electrons and protons are consumed in cathode. They combine with oxygen to give water.

The microbes have the ability to produce electro-chemically active substances consisting metabolic intermediates or final products of fermentation [8]. When microbes consume a substrate such as glucose in aerobic conditions they produce carbon dioxide and water. However in the absence of oxygen, they produce carbon dioxide, protons and electrons [9].

The bacterias then are made to use inorganic mediators to trap the electron transport chain and to accept the electrons. The mediator crosses the outer lipid membranes and plasma wall then it begins to liberate electrons from the electron transport chain. The reduced mediator exits the cell with electrons that are carried to electrode for deposition. This electrode is the negatively charged electrode. The release of the electrons means that the mediator is oxidized and ready to repeat the process. It is important to note that this happens under anaerobic conditions only. If oxygen is present, it will collect all the electrons because of greater electro-negativity compared mediator. A number of mediators have been suggested for use in microbial fuel cells. These include neutral red, methylene blue, thionine, resorfuin etc. [10].

In order to turn this into a usable supply of electricity, this process has to be accommodated in a fuel cell. To generate a useful current, it is then necessary to create a complete circuit.

The mediator and the microbes are mixed together in a solution and added with a suitable substrate/biomass. This mixture is placed in a sealed chamber to carry out fermentation or anaerobic respiration. An electrode is placed in the solution to act as the anode. In the second chamber of the MFC, there is placed another solution and an electrode. This electrode, the cathode, is positively charged and is the equivalent of the oxygen sink at the end of the electron transport chain. It is absolutely external to the biological cell. The solution used is usually an oxidizing agent that takes up the electrons at the cathode. This requires large volumes of circulating gas. A more practical approach is to use a solution of a solid oxidizing agent.

MATERIALS AND METHODS

Chemicals: Dextrose, proteose peptone, beef extract, NaCl, neutral red, theonine, potassium ferricyanide, ferroin indicator, ferrous ammonium sulphate , potassium dichromate , concentrated sulphuric acid , NaOH, HCl, ethanol, agar.

Materials Required: Polyacrylic bottles (250 ml), PVC pipe, copper wire, graphite rods, multimeter, M-seal.

Glass Wares: Burette, conical flask (500 and 250 ml), test tubes, beakers (500 ml) and pipette.

Bacterial Culture: *Clostridium sporogenes* (ATCC No. 19404) was obtained from NCIM, Pune, India. The cultures were maintained on cooked meat medium (beef extract- 4.5g, dextrose- 0.2g, proteose peptone-2g, NaCl-0.5g, distilled water -100 ml).The medium pH was initially adjusted to 7.2 and the inoculum was introduced into the media at ambient temperature. The inoculated cultures were incubated at room temperature.

E coli cultures available in department were maintained on agar slants at room temperature.

Substrates: The various substrates used in the study were rice wash water, kitchen waste water and sewage water.

Construction of MFC

A double chambered microbial fuel cell (MFC) was constructed. 250 ml PAC bottles were used for the construction of the two chambers and were connected with agar salt bridge (3% NaCl agar) having a length and diameter of 6 cm and 2 cm respectively.5cm long graphite electrodes were used in each chamber. The electrodes were connected to the multimeter and a resistor of resistance 22 **Ω** was connected in parallel to the multimeter. The containers were kept air tight during the entire process.

Preparation of Salt Bridge: A water solution containing 3% NaCl and 1.6% Agar in a conical flask was allowed to boil inside a microwave oven for nearly 3 minutes at high temperatures.

The hot solution was then poured into cut PVC pipe sections each of length 4 inches by sealing one end of the PVC by polythene. The setup was then allowed to cool for nearly 2.5 hours inside a **HEPA** Filter. The salt bridges were thus made ready for use.

Running of MFC

- The bacteria which were fully grown for the duration of 48 hours were used as inoculum.
- 2 ml of inoculum was added to the anodic chamber containing 350 ml of waste water sample.
- Mediators like the onine and neutral red was added into anodic chamber.
- 350 ml of potassium ferricyanide was added into cathodic chamber.
- External circuit was completed by connecting the electrodes to the multimeter using copper wire and a resistance of 22 Ω was applied.

After the experimental set up, the first datum was taken after 1 complete day. In this way consecutive datum was taken for 6 days. The values noted were the peak values observed during the process of measurement of the data.

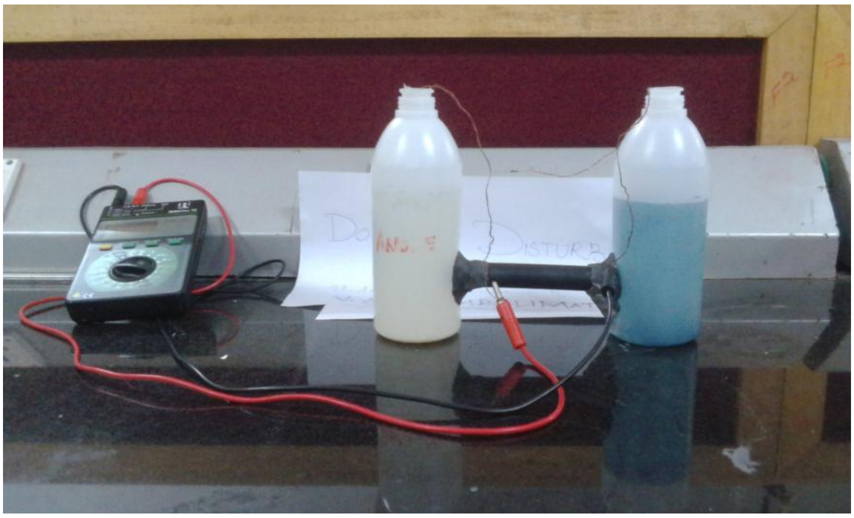

Figure 1: Double Chambered Microbial Fuel Cell

Effectiveness of an MFC in Organic Matter Removal

OBSERVATIONS

Performance of Microbial Fuel Cell

Table 1: Voltage Generated Using Different Waste Water Samples for Escherichia Coli

Substrate	Voltage in mV					
	24hrs	48hrs	72hrs	96hrs	120hrs	144hrs
• Rice wash water	6	15	18	23	29	19
• Sewage water	31	46	62	78	84	69
• Kitchen waste water	13	21	33	38	49	39

Table 2: Voltage Generated Using Different Waste Water Samples for Clostridium Sporogenes

Substrate	Voltage in mV					
	24hrs	48hrs	72hrs	96hrs	120hrs	144hrs
• Rice wash water	44	57	62	96	121	106
• Sewage water	96	139	156	171	188	169
• kitchen waste water	52	65	78	102	134	108

Table 3: Values of Chemical Oxygen Demand for Clostridium Sporogenes

Substrate	COD in mg/L (before)	COD in mg/L (after)	% Reduction in COD
Rice wash water	256	96	62.5
Kitchen waste water	274	130	52.55
Sewage water	345.6	108.6	68.57

Table 4: Values of Chemical Oxygen Demand for Escherichia Coli

Substrate	COD in mg/L (Before)	COD in mg/L (After)	% Reduction in COD
Rice wash water	256	149.2	41.7
Kitchen waste water	274	181.6	33.7
Sewage water	345.6	126	63.54

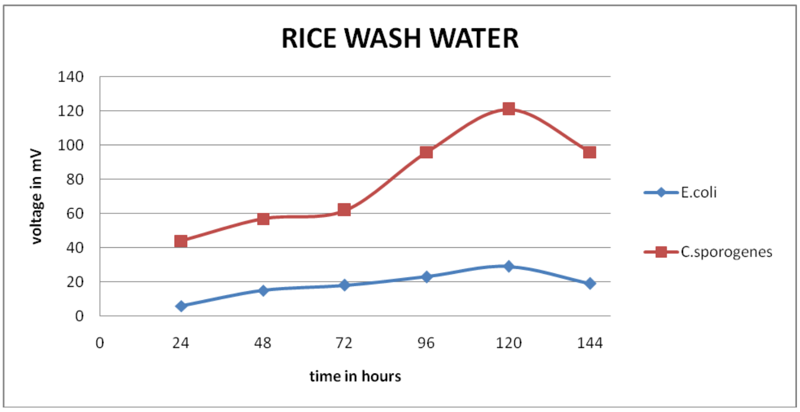

Figure 2: Showing the Comparison of Voltages Generated When Rice Wash Water Was Used As Substrate

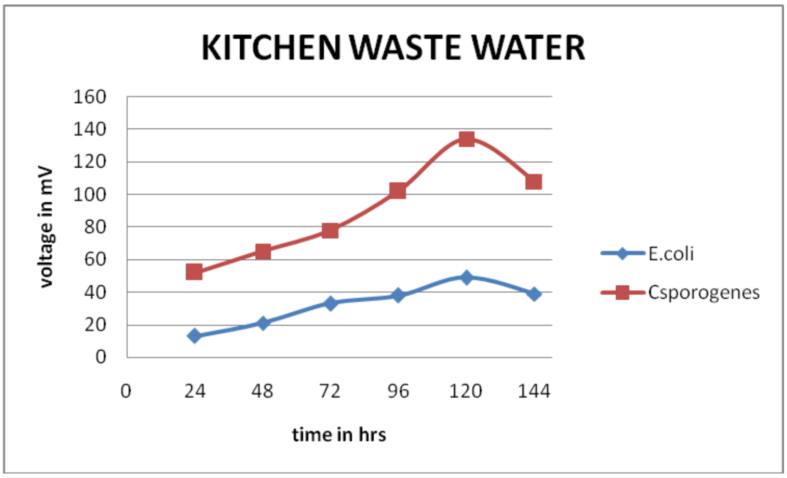

Figure 3: Showing the Comparison of Voltages Generated When Sewage Water Was Used As Substrate

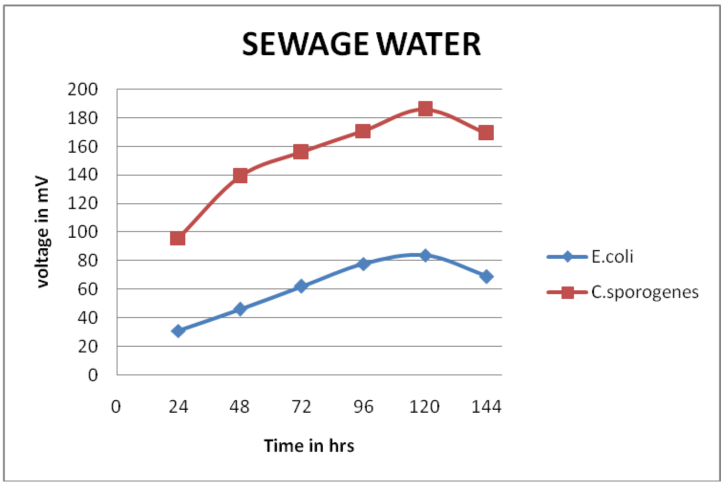

Figure 4: Showing the Comparison of Voltages Generated When Kitchen Waste Water Was Used as Substrate

DISCUSSION OF RESULTS

From table 1 and table 2 we can observe that the optimum voltage was obtained after 120hrs.

The maximum voltage of 84mV was obtained for sewage water when *E.coli* was used as the inoculum. The maximum voltage of 188mV was obtained for sewage water when *Clostridium sporogenes* was used as the inoculum.

The maximum % reduction of COD, observed in case of sewage water when *Clostridium sporogenes* was used as inoculum was 68.57.

CONCLUSIONS

The study presented above has mainly provided a review of the concept of microbial conversion of biomass into usable energy. An overview of Microbial Fuel Cells (MFCs) has been given, and their significance has been outlined.

Under present investigation, membrane less MFC was used effectively for sewage wastewater treatment with COD removal about 68% for *Clostridium sporogenes* and 63% for *E.coli*.

The optimal voltage production of the MFC observed was 188mV for *Clostridium sporogenes.*

If power generation in these systems can be increased, MFC technology may provide a new method to offset wastewater treatment plant operating cost, making wastewater treatment more affordable for developing and developed nations. With continuous improvements in microbial fuel cell, it may be possible to increase power generation rates and lower their production and operating cost. Thus, the combination of wastewater treatment along with electricity production may help in saving of millions of rupees as a cost of wastewater treatment at present.

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